1 Introduction

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The development of water economic methods and their applications is a mirror image of the development of civilization and its use of water. Roughly speaking, as early as the 1950s through the 1960s, water economics began focusing on optimal production decisions and allocation among consuming activities – at that time applied mainly to irrigated agriculture. Water scarcity had yet to be recognized as a global problem, and inter-sectoral competition had not been studied. With the growth in population, development of hydropower facilities and intensification of industrial production in the 1970s and early 1980s, water economics turned its attention to addressing economic questions of urban water supply, hydropower decisions and inter-sectoral water allocations. Soon after, when water and environmental pollution developed into a social problem, impacting environmental amenities in many places, the profession experienced an expansion of economic work to include valuation of environmental amenities, economics of water treatment and pollution control, and the economics of water ecosystems. Finally, between the mid-1990s and today, with the realization that institutions are important aspects of water management, and with the increased conflicts over shared water and the beginning of the internalization of the role of climate change in water resources, the field of water economics has witnessed a rise in works and methods applied to address institutional approaches, international water management and questions related to climate change. In addition, with increased realization of the role that nonmarket values of environmental amenities play in water allocation decisions, and with the increased need to understand behavioral responses to policy interventions, we have also seen during the 1990s an increase in the use of nonmarket valuation studies and laboratory experiments that aim to understand the strategic behavior of individuals and water agencies. For further and more detailed descriptions of how water resource economics has evolved over time, see Young and Haveman (1985), FAO (1993) and Hanemann (2006).

As of today, water economics has its footprint in many subtitles, such as institutions, sustainability, climate change, surface water, groundwater, industrial water, residential water, wastewater, water for ecosystems, hydropower, biofuel, experimental economics, nonmarket valuation, nonpoint source pollution, salinity pollution, water and development, water and health, water and growth, conjunctive management of water resources and management of international water, to name only a few. Our book is intended to be a reflection of current as well as the seminal research across this typology of water economics that has developed over the years.

HANDBOOK STRUCTURE AND CHAPTER CONTENTS

The handbook is divided into eight parts, reflecting major fields of water economics that have evolved over the years. We elected to summarize each of the chapters within each part and to demonstrate the interaction between the chapters.

Part I: Concepts and Theoretical Foundations

Chapters in this part provide basic foundations to key concepts in water economics, such as performance of institutions, sustainability and vulnerability, and adaptation to climate change.

Chapter 2 (Jaeger) deals with institutions and water. Institutions have been recognized as the necessary glue that connects economic instruments to policy goals. Good, bad or the lack of institutions often explains differences in policy achievements of water management. The chapter explores how water's characteristics, its private and public values and uses, and the kinds of users and uses influence the relative success or failure of different kinds of institutional mechanisms. The role of transaction costs and uncertainty receives attention, as well as the roles of private property rights, common-pool resource management and public property.

Chapter 3 (Knapp and Franklin) addresses the important concept of sustainability. The authors consider the implications of different definitions of sustainability for a community with access to groundwater. Making the case for sustainability as measured in terms of household utility, the authors extend a standard groundwater model to include household utility and saving/dissaving from a financial asset in the household disposition. The chapter analyzes the inter-generational equity and efficiency outcomes under three behavioral regimes of the decision maker, which include exploitation under common property usage, exploitation assuming utility maximization and exploitation under utility maximization subject to a sustainability constraint. In addition to providing the analytical and numerical solutions under each regime, the chapter also provides the policy implications associated with each solution.

Chapter 4 (Hurd) is a review of methods for assessing economic impacts from climate change on water resources. Because both the complicated pathways through which climate change affects the water system, and through that media, the rest of the economy, well-designed and well-executed assessments of climate change impacts and adaptation strategies are very useful for policymaking. The author highlights two principal approaches to the estimation of possible climate change impacts involving water and agriculture, hydro-economic models and the cross-sectional statistical models, often referred to as the Ricardian approach. As well as describing these two approaches, the chapter reviews selected and recent empirical applications of each approach to various locations.

Part II: Sectoral Focus

The eight chapters in this part review and analyze different issues related to sectoral water use and management, starting with the traditional water-using sectors and concluding with the environment and ecosystem use. These chapters identify the potential

role of incentives and institutions, and the importance of interactions between resources and across their users.

Chapter 5 (Wheeler et al.) focuses on agricultural water management. As the largest extractor of the world's surface and groundwater resources, irrigated agriculture deserves special attention, as its management practices affect the rest of the sectors competing for water. The chapter outlines factors driving irrigation water supply and demand, the benefits and externalities that irrigation may generate, and how water policy design can enhance the economic, social and environmental value realized through irrigation into the future. Special attention is given to arid regions with highly developed economies and water resources, such as the USA, Australia and Spain, where the area under irrigation is in decline due to physical, institutional and regulatory reasons. The developing economies are also examined, where irrigation is growing through unprecedented expansion of groundwater irrigation with negative externalities due to lack of proper institutions and regulations, such as in India, Mexico and Southeast Asia. The chapter covers key agricultural water management issues and highlights the prime challenges of irrigated agriculture in the future, including water scarcity, water quality and conflict between competing uses.

The economics of industrial water use is discussed in Chapter 6 (Renzetti). Although less emphasized in the literature as such, water use by large industrial facilities can affect regional water availability and quality. This chapter provides a critical assessment of recent research regarding the economic characteristics of industrial water demands. Of particular interest are recent research lines that examine the determinants of internal water recirculation decisions by firms (water reuse), the valuation of industrial water use and the incorporation of water into computable general equilibrium models. In addition, the chapter assesses how these recent research efforts may contribute to improved water policies and management.

Various economic aspects of residential water management are addressed in Chapter 7 by Smith and Zhao. The chapter focuses on policy instruments to demonstrate management's real value to the household user and in curbing consumption. The chapter addresses the following points: (a) how should policy analysts think about the availability of water in considering the management of residential demand?; (b) what can be learned from price and non-price policies to manage residential water use?; (c) how do policies that influence goods that are complementary to water affect the design and evaluation of residential water management policies?; and (d) should climate uncertainty play a role in current residential water management?

Koundouri and Dávila (Chapter 8) demonstrate the use of the ecosystem services approach in guiding water valuation and management in the EU context of the Water Framework Directive. The authors develop an interdisciplinary methodology for identifying water-related ecosystem functions and ecosystem services for humans, which are then monetarily evaluated using market and nonmarket valuation methods. The methodology is then applied to selected case studies on inland and coastal waters to demonstrate how it can facilitate the implementation of various related EU directives.

Burnett et al. (Chapter 9) argue that managing water resources independently may result in substantial economic losses when those resources are interdependent with each other and with other environmental resources. The chapter develops a system that incentivizes the management of interdependent resource management across watersheds,

groundwater and coastal ecology. The authors develop general principles for using resources with spillovers, including corrective taxes and subsidies for incentivizing private resource users to internalize the externalities they create. The methodology is then applied to analyze specific cases of managing water resources, including groundwater systems with spillover effects between upstream and downstream users.

A somewhat similar philosophy of accounting for spillover effects, yet now in the management of hydropower, is presented in Chapter 10 by Johansson and Kriström. The chapter addresses interactions between hydropower production and the electricity market. The authors develop the theoretical properties of a benefit–cost analysis (BCA) of a proposed win–win approach of hydropower re-regulation, involving two or more rivers. The approach is applied to the Nordic Nord Pool spot market. Given the description of benefits and direct and indirect costs, the authors first present a simple benefit–cost rule for small projects plus a remainder term that can be extended to accommodate large projects.

In Chapter 11, Zilberman and Kaplan develop a framework to analyze the interaction of water, land use and the environment when dealing with biofuel production. The chapter demonstrates that the exact effect of biofuel on land, water and the environment depends on policies used to induce the expansion of biofuel, investment in R&D, and regulation of technologies. The chapter applies an analytical framework to demonstrate the effects of different policy interventions used by governments to regulate biofuel production.

Grafton and Squires (Chapter 12) review the economics of water from a renewable resources perspective, focusing on fishery resources. They develop an economic framework to optimize extractions under various property rights regimes and incentives (see Jaeger, Chapter 2, this volume). The interaction of water and fisheries is developed following recent market failures in both types of resources (i.e. water and fisheries). Key management opportunities and challenges common to both water and fisheries are discussed in the context of ecosystem services, including the role of economic incentives (see Burnet et al., Chapter 9, this volume), the stochastic nature of water and fisheries resource replenishment, and the interaction of existing institutions and economic policy instruments.

Part III: Water Sources

We included two chapters in this part. The first focuses on surface water allocation efficiency, and the second addresses the economics of wastewater management and reuse.

Ward (Chapter 13) reviews several recent developments in economic theory and methods for the analysis of policies that aim at protection, conservation, development, application, depletion, sharing, treatment and sustaining of surface waters. The author applies concepts from the theory of economic efficiency, which provides decision-makers with a way to compare impacts of two or more water policy choices in which impacts occur over many time periods, over many water uses, for several quality levels and for many locations. The chapter demonstrates that economic efficiency, measured as the difference between added benefits and added costs, can inform water managers and stakeholders about economic impacts of water programs to address transboundary water management, water rights systems, drought adaptation, integrated management,

water conservation, backstop technologies, scales of development, climate, water and food security, water accounting and water markets.

Hernández-Sancho and Molinos-Senante (Chapter 14) develop a framework to analyze policies aimed at wastewater management and reuse. With many regions, especially arid regions, confronting severe water scarcity, water reuse has emerged as a popular alternative because it increases water supply, and so lessens the pressure on conventional natural resources. At the same time, it reduces pollution by discharging less untreated wastewater into the environment. With their analytical framework, the authors demonstrate that, when new facilities are planned, it is necessary to predict the operation and maintenance costs of water reclamation plants. Not only are total costs important, but also the relationship between costs and the quality of the water for each water regeneration process. According to the concept of sustainable development, a water reuse project must comply with environmental, socio-cultural and economic needs to be deemed sustainable. The recycling of water not only contributes to increasing the availability of water resources, but also might involve significant environmental impacts (positive and negative). The proposed analytical framework is applied to a case in Valencia, Spain, to demonstrate its relevance.

Part IV: Alternative Approaches to Valuing Water

Two approaches for valuing water and water policies are highlighted in this section – experimental economics and nonmarket valuation. Both approaches are relatively new, compared with the economics associated with many of the other topics in this book. The use of both approaches in economics has gained significant prominence as a means to better understanding personal preferences and strategic behavior in water-related decisions.

Bejarano and Shortle (Chapter 15) review the role experimental economics plays in water resources dilemmas. They explain that experimental research on market and non-market water allocation mechanisms has uncovered new insights into the relationship between rules, information and allocative efficiency. Experiments have also advanced understanding of how information, the degree to which actions are observable and monitored, and individual characteristics affect water-related choices. Experiments allow researchers to observe an individual's actions as well as to implement and elicit certain individual characteristics, such as cost and risk aversion, that are unobserved or unusable given their private nature in naturally occurring data. The chapter reviews applications of experimental methods to economic research on water management, trade and use, and suggests new avenues for the application of experimental economics to water questions.

Carson (Chapter 16) reviews the development and applications of nonmarket valuation in water resource management. Because many elements and services associated with water resources (e.g. recreational attributes) are not traded in markets and thus are not priced, there is no easily computable market value to assign to them for use in benefit–cost analysis. Consequently, the value associated with these services and attributes are often left out of benefit–cost analyses, resulting in biased analyses that favor misuse and/or overuse. This chapter reviews the history of development nonmarket valuation methods to address this serious oversight, including the travel cost method,

the contingent valuation method and the household production function method, which were mainly used for recreational analysis of water resources and water quality valuations. Another major nonmarket valuation technique, the hedonic pricing method, also featured prominently in early efforts to look at the impacts of water projects and water-related policies. It has seen less, but still substantial, use in valuing proximity to water bodies and the capitalization of other water-related amenities into land prices. The chapter then reviews empirical applications of nonmarket valuation techniques to water resources in their contemporary use.

Part V: Water Quality Management

While managing water on the ‘quantity’ side has received and still warrants significant attention, the ‘quality’ issues surrounding water management deserve equal billing. Water pollution is a multifaceted problem, affecting not only the types of use associated with water, but also the quantity of use, given that the value of water in particular uses depends on its quality. As such, quantity and quality are intricately linked. In the two chapters that follow, research is presented addressing two of the most significant water quality problems confronting society today: nonpoint source water pollution and salinity. The chapters employ process-based programming models to evaluate economic issues surrounding nonpoint source pollution regulation and groundwater salinization, both of which jeopardize sustainability of many agricultural ecosystems globally.

Baerenklau and Wang (Chapter 17) review model-based approaches for the regulation of nonpoint source water emissions. Because of the diffuse nature of such emissions, nonpoint source polluters cannot be observed and efficient policies to curb their pollution are challenging to develop. This chapter provides an overview regulation based on modeled estimates of emissions or pollution, rather than on directly observed quantities. The authors focus on emerging research directions; discuss the advantages and disadvantages of model-based regulation; describe generally how to develop a model-based regulation; present recent examples illustrating potentially beneficial applications of this approach; and outline directions for future work.

In Chapter 18, Schwabe and Knapp address the fact that, while groundwater resources in many semi-arid regions are a significant source of water for irrigation and residential supply, such sources are increasingly becoming more saline. They argue that groundwater salinization and the rate at which it occurs is a function of many inter-related factors, including imported surface water and soil salinity, agricultural practices surrounding crop choices and irrigation management, aquifer characteristics and institutional policies (see also Tsur, Chapter 21, this volume). The chapter develops a hydro-economic model of regional irrigated agriculture production in the presence of two water supply sources – imported surface water supplies and groundwater – to investigate how irrigated agriculture both impacts and responds to the groundwater system, which is characterized in both a quantity and salinity dimensions.

Part VI: Addressing Water Scarcity

The chapters in this part address water scarcity from different angles: water markets, water conservation and conjunctive management of water resources.

In Chapter 19, Hansen reviews the development and application of water markets and their effectiveness. The author identifies several advantages of water markets, such as allowing water agencies to both reduce water scarcity without constructing new supply sources and manage supply variability, especially in drought-prone regions. Well-functioning water markets create an incentive to improve water-use efficiency and, somewhat noteworthy, have been used with some success in addressing environmental benefits. Among the problematic issues identified in the chapter are transaction costs broadly defined as transportation, third-party and environmental impacts and institutional barriers. The discussion of water market performance focuses primarily on applications within the western USA, yet references to water markets elsewhere are included.

Dupont, in Chapter 20, describes different approaches to water conservation in the residential sector. This chapter describes the different approaches water utilities have adopted to conserve water, including price-based and non-price-based approaches, and then presents models that have been used to examine the relative effectiveness of these approaches and the potential synergies between them. Case studies of three different types of water conservation policies aimed at addressing water scarcity concerns are examined. The chapter includes examples of several studies that have looked at the cost-effectiveness of several water conservation programs aimed at addressing water scarcity.

Management of water resources in agriculture is discussed by Tsur in Chapter 21, by developing a framework to manage surface and ground sources conjunctively. The author revisits and extends previous work on the stabilization role of groundwater, provides empirical evidence on its economic value and discusses policy implications. The chapter emphasizes the stochastic nature of surface water relative to the (often) more stable groundwater supplies. This feature gives rise to the stabilization (or buffer) value of groundwater and bears important policy implications regarding water management policies.

Part VII: Transboundary Water Management

Chapters in this part provide examples of various approaches to evaluate allocation problems surrounding shared water across political boundaries, often within the context of international water. The chapters present research that employs both game-theory and non-game-theory methods to address such issues in the context of scarce international water. While the first chapter focuses on water scarcity in the quantity dimension, the second also includes the quality (pollution) dimension.

Dinar (Chapter 22) addresses joint management of international water bodies under scarcity and variability. The chapter focuses mainly on cooperative arrangements, such as utility and non-utility transfer arrangements, issue linkage and self-enforcing rules. Examples, using published work, from the Nile, Aral Sea and the Mekong basins are used to demonstrate relative advantages and disadvantages of various joint management arrangements under varying situations of climate change-induced water scarcity.

Ansink and Houba (Chapter 23) introduce the economics of transboundary water allocation, focusing on water scarcity and pollution. Using game theory, the authors evaluate transboundary water allocation, with particular attention to strategic aspects. The models developed in this chapter shed light on how conflict and cooperation over

transboundary water resources may occur. Among the concepts addressed are efficiency, sustainability and fairness of the allocation solutions, with illustrative examples of each.

Part VIII: Water in the Developing World

In this part, we present two chapters that address issues related to water and the developing world. The first chapter discusses the economics of water and sanitation and how to assess the value of such water projects in the developing world. The second chapter reviews the literature to identify and explain possible connections between water and growth in the developing world.

Whittington and Pattanayak (Chapter 24) discuss the existing methods that apply benefit–cost analysis to potable water supply and sanitation sector projects. The chapter offers reflections on the challenges confronting researchers in their efforts to conduct economic analyses of potable water and sanitation investments. The main features of the chapter include a review of the different methodological approaches that have been used to estimate benefits from water and sanitation investments, including both revealed and stated preference techniques. A discussion of key challenges that need to be considered in the design and execution of most economic analyses of potable water supply and sanitation investments is also provided.

Barbier (Chapter 25) reviews research exploring the relationship between water and growth in developing countries. The author departs from the question of whether increasing water use and scarcity may impose constraints on the growth of developing countries. Through the development of an empirical growth model, the chapter explores this potential relationship by examining the possible influence the rate of water utilization has on economic growth. Using a global dataset of water use and growth, the author finds a robust ‘U-shaped’ association between the ratio of freshwater withdrawal to total actual renewable water resources and growth; consequently, for many developing countries these results suggest that, as the rate of freshwater utilization increases, the growth rate of the economy declines. The author discusses these unexpected findings and identifies possible explanations, including the presence of inefficient water policies and the necessity for substantial reform.

SUMMARY

The 24 chapters in this handbook cover a continuum of topics that separately and jointly represent state-of-the-art water economics these days. Each chapter covers issues, methods and applications that demonstrate the role of economic theory and applications in management of water resources. We will learn about the role of institutions in allowing a sound water policy; how sustainability is conceptualized, applied and interpreted in water resource management; how important is it to appropriately measure climate change economic impacts and adaptation of the water sector; how decisions for extraction and use of surface water and groundwater are interwoven. We will also learn how economic instruments are used in decision-making and welfare evaluation in industrial water use, residential water use, and wastewater treatment and reuse, and conjunctive management of these water resources. The book addresses economic concepts of water

for ecosystems; tradeoffs between development and the environment when deciding on hydropower development; and the opportunity cost of biofuel production. We will find out about the role of experimental economics in water consumption and the use of related behavior. We will learn about the developments of the field of nonmarket valuation, the various approaches to nonpoint source pollution control and salinity pollution. We will be familiarized with issues related to water and the developing world – in particular water and health, and water and economic growth, management of international water.

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